Diversity Study of the Culturable Magnetotactic Bacteria from the Sediments of Shipra River in Madhya Pradesh and their Application in Enzyme Immobilization and Heavy Metal Bioremoval from Wastewater

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Synopsis

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DECLARATION

I, **Prachi Magre** registered as a research scholar (Registration number-2105PHDLS08337) in the faculty of Doctoral Studies & Research, Shri Vaishnav Vidyapeeth Vishwavidyalaya, Indore, do hereby declare that the synopsis of the research project titled "**Diversity Study of the Culturable Magnetotactic Bacteria from the Sediments of Shipra River in Madhya Pradesh and their Application in Enzyme Immobilization and Heavy Metal Bioremoval from Wastewater**" has been prepared by me and the work is authentic.

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Introduction

Prokaryotes having directed active movement that is guided by geomagnetism are collectively called **magnetotactic bacteria (MTB)** (Bazylinski, *et al.*, 2013).

MTB mainly inhabit aquatic ecosystems ranging from freshwater to hypersaline environments. Most MTB are microaerophilic, although there are some obligately anaerobic strains usually found at or below the oxic-anoxic interface of chemically stratified water columns or sediments Araujo *et al.*, (2015). Especially, the environment with low to moderate iron content is most appropriate for MTB, which has a correlation between the blooms of MTB (Singh *et al.*, 2018).

Magnetotactic bacteria (MTB) are a morphologically, phylogenetically and metabolically diverse group of prokaryotes that share the ability to biomineralize intracellular magnetic nanocrystals surrounded by a lipid bilayer (biological membrane). These structures, referred to as magnetosomes, are either composed of iron oxide, greigite (Fe_3S_4), magnetite (Fe_3O_4), or the iron sulfide, Bhat *et al.*, (2020). Bacterial magnetosomes size range from 30 to120 nm. This size range is ideal for a large number of biomedical and other biotechnological applications such as carriers in magnetic drug targeting, to raise the efficiency of tumor treatment by hyperthermia, MRI applications, extraction of DNA and mRNA from different biological samples, magnetosome-based immunoassays to detect antigens, environmental pollutants, hormones and toxic substances (Prabhu and Kowshik, 2016; Singh *et al.*, 2018).

The magnetosome-containing cell acts like a motile, miniature compass needle where the cell swims parallel to the magnetic field lines. The synthesis of magnetosomes are under strict genetic control by a process called biomineralization. The initial researches on magnetosomes showed that the magnetosomes are spheroid in shape but later it was

observed that the morphology of magnetosomes varies with the bacterial strain. The shape of magnetosomes includes cubo-octahedral, bullet-shaped, elongated prismatic and rectangular morphologies (Jacob and Suthindhiran, 2016).

Objectives

- Screening and characterization of magnetotactic bacteria from the water and sediments of Shipra River in MP.
- Optimization of process parameters for the large scale cultivation of magnetotactic bacteria.
- Characterization of magnetosome and optimization of process parameters for enhanced production of magnetosome.
- Application of magnetosomes in enzyme immobilization and MTB in heavy metal bioremoval from wastewater.

Objective 1- Screening and characterization of magnetotactic bacteria from the water and sediments of Shipra river in MP.

- Collection of sediments and water sample from Shipra River from different selected sites.
- Analysis of collected samples for pH, temperature, Dissolved Oxygen, BOD_5, Electrical Conductivity, TDS, Fe (II) and total Fe, nitrate and sulphide content.
- Enrichment, screening and isolation of magnetotactic bacteria.
- Light microscopy for MTB isolation and study of morphological features of isolated MTB.
- Identification of MTB and construction of the phylogenetic tree.
- Scanning Electron Microscopy for visualization of magnetosomes.

Objective 2 - Optimization of process parameters for large scale cultivation of magnetotactic bacteria.

- Optimization of pH, temperature, nutrients for MTB growth.
- Assessment of cell growth and magnetosome formation.

Objective 3 - Characterization of magnetosomes and optimization of process parameters for enhanced production of magnetosomes.

- Extraction and characterization of magnetosomes from selected MTB.
- Optimization of pH, temperature, nutrients for magnetosome formation.
- Scanning Electron Microscopy for visualization of magnetosomes.

Objective 4 - Application of magnetosomes in enzyme immobilization and MTB in heavy metal bioremoval from wastewater.

- Standardization of techniques for immobilization of enzymes on MTB associated gel beads and estimation of immobilization efficiency.
- Standardization of technique for MTB isolation under magnetic field and recovery of heavy metals from MTB.
- Assessment of absorption kinetics.

Rationale of the Study

At this time, there are roughly 25 species of magnetotactic bacteria available in axenic cultures. Regardless of this, only a few species are available in national and international cell line repositories (Vargas *et al.*, 2018).

To address this question, further sampling operation in extreme environments will need to be done by researchers using specific culture-

and non-culture-based techniques. Also, considering the relatively small number of research groups that study these intriguing organisms, it seems that the known ecological diversity of MTB is seriously underestimated (Bazylinski, *et al*., 2013).

The ecology of the MTB has also been studied all over the world including the North Sea, Brazilian and pacific lagoons, China sea, coastal salt ponds, Asian rivers and lakes, American and European continents Islam, Peng and Ali, (2018). However, little is known about MTB inhabitation in the Indian ecosystem.

MTB inhabit marine, estuarine and freshwater habitats where vertical chemical concentration gradient exists. In the natural environment, they have a preference to inhabit the oxic–anoxic interface (OAI) that implicates the uppermost fraction of un-stratified sediments based on the environment. The presence of magnetosomes helps the bacteria in locating favorable growth conditions at or just below the OAI of aquatic sediments (Jacob and Suthindhiran, 2016).

Studies show that the environment with low to moderate iron content is most appropriate for MTB Singh *et al*., (2018). Iron exists naturally in rivers, lakes, and underground water also. It may also be released to water from natural deposits, industrial wastes, refining of iron ores, and corrosion of iron-containing metals (Ravi Sankar and Prasada Rao, 2014).

The Shipra River, also known as Kshipra, is a river in Madhya Pradesh state of India. The shipra river rises in the North of Dhar district, and flows north across the Malwa Plateau to join the Chambal River at the MP-Rajasthan boundary in Mandsaur district. The length of Shipra River is 195 km. (https://en.wikipedia.org/wiki/Shipra_River).

As new strains of MTB will be isolated, further of their genomes become available, the function of further magnetosome proteins are illustrated, and new molecular techniques are developed, the numbers of commercial, scientific, and biomedical applications of magnetosomes and bioinspired magnetic nanoparticles will increase and become more widespread especially as economically viable strategies emerge for the production of these structure (Araujo *et al.*, 2015).

A major obstacle in the utilization of MTB technology from laboratory to industrial as well as commercial scale is the difficulty in growing magnetotactic bateria and produce high yield of magnetosomes under artificial environmental conditions. Eventhough several types of culture media have been developed for yielding higher quantity of magnetosomes however, cultivation of magnetotactic bacteria is still difficult because of their different metabolisms Araujo *et al.*, (2015). Different control strategies have also been estimated for attaining proficient magnetosome yield (Basit *et al.*, 2020).

The metal consumption rate is increasing rapidly in accordance with the exponential population growth and the advancement of production technologies. Metal contamination owing to anthropogenic sources is a persistent global issue, having environmental, political and medical implications. The main source of heavy metal pollution are mining, milling, plating and surface finishing industries that discharge a variety of toxic metals such as Chromium, Copper, Cadmium, Nickel, Cobalt, Zinc and Lead into the environment. Over the last few years, the concentration of these heavy metals in river water and sediments has increased rapidly. Consequently, concentrations of toxic metals in grains and vegetables grown in contaminated soils have increased. This poses a serious threat to humans and the environment because of its toxicity,

non-biodegradability and bioaccumulation (Central Water Commission, 2018).

There are various wastewater treatment technologies available for treating heavy metals contaminated water for example chemical precipitation, evaporative recovery, oxidation/ reduction, filtration, ion exchange, membrane technologies, and electrochemical treatment technologies. Sorption is a method well known for its cost-effectiveness in metal removal. It is widely used in many countries, especially in developing and transition countries, where expensive, advanced technologies cannot be afforded. Sorption is an effective physico-chemical process for removing heavy metals from wastewater, especially for treating wastewaters with a low metal concentration. This process is very effective and relatively cheap if low-cost adsorbents are used. There are many adsorbents available, varying from natural materials (clay balls) to agricultural waste and waste materials (sludges) (Central Water Commission, 2018).

MTB has also been considered a potent bioremediation tool against toxic metals, where the idea of co-biomineralization of other heavy metals in magnetosome synthesis along with iron has been thought upon. MTB possesses remarkably diverse respiratory capacities, including the ability to reduce metals like Fe (III), copper, lead, nickel and zinc. Furthermore, Certain strains of MTB demonstrate Au\\Cu and Cu\\Ag binary ion systems in selective reinforced competitive biosorption for Au (III) and Ag (I) (Jacob and Suthindhiran, 2016).

This might be due to the fact that MTB have a high specific surface area, charge opposite to that of pollutant ions, high binding energy per unit surface area, and strong oxidative capacities of metals oxides. Microbial strain matrix can enhance the interaction between pollutants and metal and are easy to separate from biomass via applied external magnetic

field/force. Magnetosomes can be synthesized and metals can be recovered in the form of metal zero-valent ions. All these properties make MTB a promising technology as a novel biosorbent (Ali *et al.*, 2018).

MTB also seems to be noble biosorbents and some research groups are actively involved in the examination of MTB reusability, biomass separation and resource recovery.

Magnetic nanoparticles and magnetosomes nowadays have grabbed much attention as matrix material for immobilization of various enzymes. Additionally, immobilization on magentosomes makes the recovery process simple and easy with magnetic separation and the protein display system of magnetosomes can be used for the expression of catalytic units. Different researchers have examined the stability of the magnetosome enzyme-complex and demonstrated that the complex retained between 90% and 100% of its activity after three cycles of usage Ginet *et al.*, (2011). This work clearly demonstrates the potential use of magnetosomes in bioremediation.

Honda *et al*., (2015) have explored the application of magnetosome-enzyme complexes in the production of biofuels. In this work, a multi-enzyme complex was constructed on the surface of magnetosomes. Cellulose degradation activity of this immobilized enzyme complex was observed to be significantly higher as compared to the non-immobilized enzymes. Additionally, the immobilized multi-enzymatic complex retained 70% its cellulose degradation activity after five cycles of utilization (Vargas *et al.*, 2018).

Considering the importance of MTB, it becomes needful to carry out studies on diverse types of MTB at a greater scale; but unfortunately, a few MTB are available in pure culture today, particularly due to lack of an unambiguous isolation technique and little success in the

manipulation of optimum microenvironmental parameters for maintenance of MTB. The present study is therefore focused on:

- Screening and characterization of magnetotactic bacteria from the water and sediments of Shipra river in MP.
- Optimization of process parameters for large scale cultivation of magnetotactic bacteria.
- Characterization of magnetosomes and optimization of process parameters for enhanced production of magnetosome.
- Application of magnetosomes in enzyme immobilization and MTB in heavy metal bioremoval from wastewater.

Review of Research and Development in the subject

(i) International Status

- Twenty-five axenic cultures of MTB have been isolated from freshwater, saline, hypersaline and brackish water in countries such as Germany, USA, China, Japan, Brazil.
- Bahaj *et al.*, (2002) used a simple Orientation Magnetic Separation (OMS) system for separating MTB and with 52% of Plutonium metal and 70% of MTB recovery was achieved.
- Song *et al.*, (2006) and (2008), in China, have reported 99.99 % of Au(III) and 98.75 % of Cu(II) biosorption yield, from artificial wastewaters, in a batch experiment using MTB *Stenotrophomonas sp.* within 10 minutes of contact time. They also developed an orientation magnetic separator (OMS) system was also developed for MTB biomass separation and its performance was calculated. The results indicated that 100% MTB separated at the magnetic intensity of 1200 GS in 180 minutes.
- Huiping *et al.*, (2007), in China, used magnetotactic bacteria for 99.8% and 99.5% recovery of Cu(II) and Au (III) from simulated

wastewater. Later, in another study in 2013, they reported that 100% MTB could be recovered at a magnetic intensity of 1200GS.

- *Magnetospirillum magneticum* AMB-1 was applied in the microbial recovery of gold from plating waste. *M. magneticum* AMB-1 successfully precipitated approximately 42% and 100% of gold from growth medium containing 10 µM gold and from a mixture of plating waste/growth medium containing 0.4 µM gold, respectively (Tanaka *et al.*, 2009).
- Cai *et. al.*, (2011) in China have reported the biosynthesis of gold nanoparticles by biosorption utilizing *Magnetospirillum gryphiswaldense* MSR-1.
- Wang *et al.*, (2011) in China, have shown selective reinforced competitive biosorption of Ag(I) and Cu(II) on *Magnetospirillum gryphiswaldense* and noticed removal of 94.90% of Ag (I) and 55.03% of Cu (II) within 10 min of contact time at pH 4 and 5 respectively.
- Au(III) and Cu(II) removal were investigated by Li *et al.*, (2013), in China, used *Magnetospirillum gryphiswaldense* (MSR-1) strain in a batch experiment and maximum 99% of Au(III) and 62.23% of Cu(II) removal was observed within 10 minutes of contact time at pH 2.5 and 5 respectively. They also noticed that at pH 1-5.5, the biosorption capacity of Au(II) varied gradually as pH increased from 1 to 5.5, reaching a maximum 99.7% at pH 2.5. However, in the case of Cu(II) biosorption, efficiency first increased quickly upto 62.23% from pH 1-5.0 and then decreased. The interference of co-metal existence was also investigated during the experiment and it was noticed that the coexistence of metals did not influence the biosorption efficiency.
- Diaz-Alarcón *et al.*, (2019), in Columbia, evaluated the capacity to remove metal ions such as Fe^{+2} and Mn^{+2} in samples of naturally

enriched groundwater, through a process of MTB inoculation, where the quantification of the rates of removal of these ions provided a diagnosis about the potential use of MTB in the treatment of groundwater. The average removal rate for the experiment were 47.86% for Fe^{+2}; 15.26% for Mn^{+2} and 46.78% for Zn^{+2}.

- The concentration of nutrients, predominantly carbon sources, severely affects the growth of magnetotactic bacteria, and subsequently magnetosome formation Liu *et al.*, (2010). Additionally, accumulation of nutrients and inhibitory constituents in the growth medium exerts a rate-limiting effect on cell growth (Basit *et al.*, 2020)
- Liu *et al.*, (2010) cultivated magnetotactic bacteria using a 'chemostat culture' technique based on pH-stat feeding to maintain efficiency of nitrogen, carbon, and iron concentrations using several organic acids. The fed-batch autofermenter system was also designed to maintain microaerophilic conditions. High magnetosome yield and cell growth was observed within less time and less energy expenditure using the chemostat culture technique.
- Zhang *et al.*, (2011) achieved maximal magnetosome yield with *Magnetospirillum gryphiswaldense* MSR-11 using a semi-continuous culture strategy. Osmotic potential of the medium was decreased by Na^{+} and Cl^{-} ion accumulation, thereby inhibiting magnetosome yield and cell growth.
- Yang *et al.*, (2011) cultured AMB-1 cells in magnetic spirillum growth medium supplemented with L-cysteine, yeast extract, and polypeptone. L-cysteine when added to the culture medium decreased the lag phase and enhanced cell growth, leading to high magnetosome production.

- Guo *et al.*, (2011) developed a fast and continuous system consisting of a high-pressure homogenizer, ultrasonic and electro-elution equipment, a Magnetic Isolation System (MIS), and magnetic stirrer for large-scale purification of magnetosomes.

All these published reports highlight MTBs' capability to handle toxic pollutants and make MTB as an attractive candidate particularly for heavy metal removal and recovery from wastewaters. In addition, the MTB biomass can easily be isolated from the solution just by applying a magnetic field and metal ions can be recovered to meet the industrial demand. In this way, isolated MTB can be reused for consecutive treatment cycles.

(ii) National Status

The occurrence of MTB has been reported from heterogeneous habitats across every continent, but reports from the Indian coast are very few.

- Magnetotactic bacteria and their applications have deeply been explored by Suthindhiran K from Marine Biotechnology and Bioproducts Laboratory, School of Biosciences and Technology, Vellore Institute of Technology, Tamil Nadu, India. They have isolated *Magnetospirillum* sp. VITRJS1 from Pulicat Lake located in Tamil Nadu, Southeast coast of India Revathy et al., (2016), *Magnetospirillum* sp. VITRJS2, VITRJS3, VITRJS4, VITRJS5, VITRJS6, and VITRJS7 from the freshwater sediment collected from Chelur freshwater lake, Kerala, India. Jacob and Suthindhiran, (2016). They have also explored the diversity of uncultured Magnetospirillum sp. from the Kerala Sedimentary Basin, India (Jacob and Suthindhiran, 2020).

- Singh et al., (2018) collected twenty-eight samples of water and sediment from various aquatic habitats in Uttar Pradesh. MTB were not obtained from the sample collected from several locations of northern India, namely Barua Sagar Tal (Jhansi), Moti Jheel (Kanpur), Yamuna River (Agra), Sandhi Bird Sanctuary (Hardoi), Ganga River (Narora Ghat), and the amount of MTB was negligible in Shekhal Jheel (Aligarh). The most appreciable amount of MTB was obtained from the sample collected from the Keetham Lake (Agra).
- Sorty and Shaikh et al., (2015), have designed a novel co-enrichment technique for the enrichment and isolation of magnetotactic bacteria. Delayed addition of iron uptake inducer and iron source enhanced magnetosomes synthesis by MTB and supported their separation from consortium using magnetic flux. They were successful in enriching and isolating both North as well as South seeking magnetotactic bacteria from various locations in Maharashtra, India.
- A short rod of magnetotactic bacteria was isolated by Karande et al., (2014) of Cuddegali Voril Soddo Iron Ore Mine, Goa, and have utilized for magnetic hyperthermia.
- Kundu et al., (2010) from Pune Maharashtra procured *Magnetospirillum magnetotacticum* (MS-1; DSM 3856) from DSMZ, Germany, and studied the changes in magnetosome features and size of bacteria under elevated concentrations of zinc and nickel. They also explored the physical characterization, biomineralization and optical trapping of MTB and strategies for enhancement in yield of MTB without affecting magnetosome properties.

Other research groups have been working upon-

- Application of Fluorescein-entrapped magnetosome for magnetically assisted photodynamic therapy (Parul *et al.*, 2021).

- Magnetosome mediated oral delivery of insulin hormone and its possible use in diabetes management (Raghuraman *et al*., 2020).
- Magnetosome-anti-*Salmonella* antibody complex-based biosensor for the detection of *Salmonella typhimurium* (Sannigrahi *et al*., 2020).
- Prevention of microbial biofilm on wound dressing by nanobiocoating using magnetosome-coupled lemon grass extract (Ravathy *et al*, 2017a).
- Toxicity of magnetosome in various models such as Onion root tip, Human blood cells, mouse macrophage cell line (J774), and fishes (Ravathy *et al*., 2017b).
- Expression and localization of Gene encoding Biomineralization in Magnetotactic Bacteria (Singh *et al*., 2013).
- Functionalization of Bacterial Magnetic Nanoparticles for Drug Delivery.

However, the applicability of MTB for metal bioremediation has rarely been explored in India. There has been a single study, conducted in Indian labs, that demonstrates the ability of *Magnetospirillum* strains in metal recovery from diode and resistors of PCB's was conducted by Sannigrahi and Suthindhiran, (2019). The strains RJS2 and RJS6 have shown maximum recovery of metals such as lead, cadmium, manganese, and copper. Furthermore, the MTB consortia exhibit better recovery compared to individual strains. The MAG1 consortium recovers the metals such as nickel, cadmium, and zinc.

Lack of research on the isolation and identification of magnetotactic bacteria from the Indian subcontinent and their application for recovery of metals from groundwater, wastewater and metal-containing solid waste, highlights the need for research.

Significance of the study

Sampling missions into different environments and microcosms will help to isolate and identify novel species of magnetotactic bacteria with novel properties and applications helping to expand our knowledge of the diversity and distribution of MTB in different environments.

The sediments of the Shipra River are rich in iron and the depths of the river support oxic-anoxic interfaces thereby supporting the growth of magnetotactic bacteria. The diversity of freshwater magnetotactic bacteria has hardly been explored. Therefore, there are chances of isolating diverse and novel magnetotactic bacteria.

The MTB biomass can easily be isolated from the solution just by applying electromagnetic separation which avoids additional microbiological filtration.

MTB can also be reused for consecutive treatment cycles by maintaining mandatory growth conditions, desired shape and size of magnetosome can be synthesized by altering/optimizing the environmental conditions, and finally, stability can be maintained by optimizing growth requirements for long term applications.

Methodology

Magnetotactic bacteria isolated from selected sampling points on Shipra River in MP and their application as-

(i) Research Design

- Sampling collection, analysis for physicochemical parameters.
- Enrichment, screening and isolation of MTB.
- Identification of MTB- Amplification of 16S rRNA genes, sequencing of 16S rRNA genes, Construction of phylogenetic tree.
- Determination of Growth Characteristics- Generation time, magnetosome characterization through TEM.
- Optimization of growth conditions for magnetotactic bacteria and magnetosome formation.
- Large Scale cultivation.
- Magenetosome Production.
- Enzyme Immobilization and estimation of immobilization efficiency.
- Heavy metal removal and estimation of Biosorption kinetics.

(ii) Sampling

Sampling site – Composite samples of muddy sediments and freshwater of the river Shipra at different points-

I Site- Ujjain, M.P.

II Site- Dewas, M.P.

III Site- Dhar, M.P.

Sample Analysis- The samples will be analyzed for pH, temperature, Dissolved Oxygen, BOD_5, Electrical Conductivity and TDS and Iron content.

(iii) Research tools/instruments

Sample collection and physicochemical analysis.

- **MTB isolation methods-** include primary separation using a magnet, as well as various magnetic trap techniques, such as 'race-track' or 'MTB-trap', MTB-column and co-enrichment techniques.
- **Identification of MTB-** Amplification of 16S rRNA genes using primers specific for magnetosome genes, sequencing of 16S rRNA genes (outsourcing), BLAST and Construction of phylogenetic tree using MEGA software.
- **Growth Conditions-** Cultivation of MTB for enhanced production of magnetosome and optimization of pH, temperature, nutrients for MTB growth in an incubator. Assessment of cell growth and magnetosome formation.
- **Microscopy-** Light microscopy for MTB isolation and studying morphological features of isolated MTB.
- **Scanning Electron Microscopy** for visualization of magnetosomes.
- **Atomic Absorption Spectroscopy** for estimation or removal of heavy metal content by MTB.
- **UV-Vis spectroscopy**-Estimation of enzyme immobilization efficiency.

Applications

Application of magnetosome for enzyme immobilization and heavy metal bioremoval from wastewater.

As a new type of magnetic material, magnetosome has better effect on enzyme immobilization Honda *et al.*, (2015). Matsunaga has used purified magnetosome as carriers to immobilize glucose oxidase and uricase, assembled into glucose and uric acid biosensors. The same glucose oxidase and uricase can also be immobilized onto the artificial magnetic particles and magnetic Zn-Fe particles Matsunaga, T *et al.*, (1996). The activity and the amount of enzyme immobilized onto magnetosome were found to be 40 and 100 times higher than those of the artificial vectors, respectively (Matsunaga *et al.*, 1996; Lins, 2015).

Due to the magnetosome, the MTB can easily move under the magnetic field, some magnetosome-producing microorganisms can adsorb heavy metals such as Fe, Ni, As, Ni, Mg, and Cu Ambashta and Sillanpää, (2010). Therefore, the heavy metal ions in wastewater can be adsorbed on to magnetosome-producing microorganisms and then removed by magnetic separation Zhou, W. *et al.*, (2012). Although some metals including Cu, Co, Cd, and Zn can inhibit the activity of MTB, many heavy metals such as Fe, Mg, Mn, Al, and Cr have no adverse effect on MTB and can be effectively adsorbed and removed, which can be used to deal with specific heavy metal wastewater (Bahaj *et al.*,1998; Yan *et al.*, 2017).

The role of magnetosome in wastewater treatment have been further studied due to its unique properties. Change has obtained super paramagnetic nano-adsorbent, and its adsorption capacity of fluoride in water can reach 38 g·kg−1, which is easy to separate from water Chang *et al.*, (2006). Tseng have prepared magnetic polymer adsorbent by combining magnetosomes with polyvinyl acetate to adsorb Cu^{2+} in

wastewater, which showed excellent removal performance (Tseng *et al.*, 2007; Yan *et al.*, 2017).

In addition, the magnetosomes are also considered as excellent noble metal adsorbent, which can be used for the recovery of precious metals Das, (2010). At the same time, the bacterial magnetosomes have high purity compared with the artificial magnetic particles, and there is no secondary pollution during removing metals from wastewater using bacterial magnetosomes Weiss *et al.*, (2004). Therefore, the bacterial magnetosome plays an important role in wastewater treatment, heavy metal adsorption, resource recycling and so on (Liu *et al.*, 2008; Yan *et al.*, 2017).

Possible Outcomes

The magnetosomes were discovered, people have been studying for more than 40 years with the successful separation and culture of several magnetosome producing microorganisms, The isolation, Screening and Characterization of magnetotactic bacteria from the water and sediments of Shipra river in MP and study of magnetosome has been carried out from the initial analysis of the morphological structure and chemical composition to the molecular and genetic level. Optimization of process parameters for large scale cultivation of magnetotactic bacteria and magnetosome and its characterization. Meanwhile, due to the uniform particle size, high chemical purity, unique magnetic properties, low toxicity and good biocompatibility, the magnetosome have been widely used in various fields. They are also used for enzyme immobilization and heavy metal bioremoval from wastewater also. Development of process with the usage of magnetotactic bacteria for bioremediation of heavy metals from wastewater.

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